



King's Research Portal

DOI:

[10.1177/1362361316687988](https://doi.org/10.1177/1362361316687988)

Document Version

Peer reviewed version

[Link to publication record in King's Research Portal](#)

Citation for published version (APA):

Vella, L., Ring, H. A., Aitken, M., Watson, P. C., Presland, A., & Clare, I. C. (2017). Understanding self-reported difficulties in decision-making by people with autism spectrum disorders. *AUTISM*. DOI: 10.1177/1362361316687988

Citing this paper

Please note that where the full-text provided on King's Research Portal is the Author Accepted Manuscript or Post-Print version this may differ from the final Published version. If citing, it is advised that you check and use the publisher's definitive version for pagination, volume/issue, and date of publication details. And where the final published version is provided on the Research Portal, if citing you are again advised to check the publisher's website for any subsequent corrections.

General rights

Copyright and moral rights for the publications made accessible in the Research Portal are retained by the authors and/or other copyright owners and it is a condition of accessing publications that users recognize and abide by the legal requirements associated with these rights.

- Users may download and print one copy of any publication from the Research Portal for the purpose of private study or research.
- You may not further distribute the material or use it for any profit-making activity or commercial gain
- You may freely distribute the URL identifying the publication in the Research Portal

Take down policy

If you believe that this document breaches copyright please contact librarypure@kcl.ac.uk providing details, and we will remove access to the work immediately and investigate your claim.

Understanding self-reported difficulties in decision-making by people with autism spectrum disorder

Journal:	<i>Autism</i>
Manuscript ID	AUT-16-0221.R2
Manuscript Type:	Original Article
Keywords:	decision-making, Iowa Gambling Task, Cambridge Gamble Task, Information Sampling Task, autism spectrum
Abstract:	<p>Autobiographical accounts and a limited research literature suggest that adults with autism spectrum disorder (ASD) can experience difficulties with decision-making. We examined whether some of the difficulties they describe correspond to quantifiable differences in decision-making when compared to adults in the general population. The participants (38 intellectually able adults with ASD and 40 neurotypical adults) were assessed on three tasks of decision-making (Iowa Gambling Task, Cambridge Gamble Task, and Information Sampling Task), which quantified, respectively: decision-making performance, relative attention to negative and positive outcomes, speed, flexibility, and information sampling. As a caution, all analyses were repeated with a subset of participants (nASD=29 and nneurotypical=39) who were not taking antidepressant or anxiolytic medication. Compared to the neurotypical participants, participants with ASD demonstrated slower decision-making, and superior performance on the Iowa Gambling Task. When those taking the medications were excluded, participants with ASD also sampled more information. There were no other differences between the groups. These processing tendencies may contribute to the difficulties self-reported in some contexts; however, the results also highlight strengths in ASD, such as a more logical approach to, and care in decision-making. The findings lead to recommendations for how adults with ASD may be better supported with decision-making.</p>

Understanding self-reported difficulties in decision-making by people with autism spectrum disorder

Abstract

Autobiographical accounts and a limited research literature suggest that adults with autism spectrum disorder (ASD) can experience difficulties with decision-making. We examined whether some of the difficulties they describe correspond to quantifiable differences in decision-making when compared to adults in the general population. The participants (38 intellectually able adults with ASD and 40 neurotypical adults) were assessed on three tasks of decision-making (Iowa Gambling Task, Cambridge Gamble Task, and Information Sampling Task), which quantified, respectively: decision-making performance, relative attention to negative and positive outcomes, speed, flexibility, and information sampling. As a caution, all analyses were repeated with a subset of participants ($n_{ASD}=29$ and $n_{neurotypical}=39$) who were not taking antidepressant or anxiolytic medication. Compared to the neurotypical participants, participants with ASD demonstrated slower decision-making, and superior performance on the Iowa Gambling Task. When those taking the medications were excluded, participants with ASD also sampled more information. There were no other differences between the groups. These processing tendencies may contribute to the difficulties self-reported in some contexts; however, the results also highlight strengths in ASD, such as

a more logical approach to, and care in decision-making. The findings lead to recommendations for how adults with ASD may be better supported with decision-making.

Keywords

Autism spectrum, decision-making, Iowa Gambling Task, Cambridge Gamble Task, Information Sampling Task

Background

Decision-making is a complex mental process, through which one of two or more possible options or actions is actively selected in order to reach a desired goal (Edwards, 1954; Huitt, 1992). People with autism spectrum disorder (ASD) report experiencing difficulties with certain features of decision-making more frequently than those without the condition (Luke, Clare, Ring et al., 2012), and a small number of studies have evidenced atypical responses on standard decision-making paradigms (e.g. Johnson, Yechiam, Murphy et al., 2006). However, it is still the case that relatively little information is available about the ways in which the decision-making of adults with ASD may be affected by the condition. This does not make it easy to make recommendations about how best to provide support.

The paucity of research in this area is surprising given the indication from a variety of sources that, even for intellectually able and articulate people with ASD, decision-making can be difficult. Autobiographical accounts, for example, describe how, for some people, the decision-making process can become ‘*locked up and overloaded with pictures coming in all at once*’ (Grandin, 2000, p2), and how having to choose ‘*on the spot*’ can be very difficult for children with ASD (Sainsbury, 2000, p101). These accounts are consistent with a teacher’s observation of delays in decision-making by children with Asperger syndrome (AS) (Winter, 2003), and parental perceptions of indecisiveness in young adults with AS (Johnson et al., 2006). Moreover, recent self-report data suggests that people with ASD frequently experience a number of difficulties in decision-making, including mental ‘freezing’, anxiety, exhaustion, slowness in reaching decisions, a tendency to collect too much information, and impaired flexibility, such as making decisions on the basis of previous choices (Luke, 2011; Luke et al., 2012).

In addition, there is a limited research literature suggesting, indirectly, that decision-making may be affected by the neuropsychological differences implicated in ASD. These include impairments in executive functions (for review, see Hill, 2004), which are associated, in other clinical conditions, with impaired decision-making (e.g. Manes, Sahakian, Clark et al., 2002; Marson, Chatterjee, Ingram et al., 1996), and high levels of

anxiety (Gillott, Furniss and Walter, 2001). Such difficulties can restrict the ability to think abstractly (Etzioni, 1988) and disturb the normal patterns of autonomic arousal present in decision-making (Miu, Heilman and Houser, 2008).

Finally, a small number of laboratory studies involving non-social tasks have investigated decision-making in ASD. The earliest of these (Johnson et al., 2006) used a version of the Iowa Gambling Task (IGT, Bechara, Damasio, Damasio et al., 1999) to assess decision-making in ambiguous situations. Compared to a neurotypical comparison group, participants (n=15), adolescents with AS (n=14) demonstrated a more erratic pattern of choices, which could result in disadvantageous decision-making (Yechiam, Busemeyer, Stout et al., 2005). In addition, using a mathematical model, the *Expectancy-Valence Learning* (EVL) model (Busemeyer & Stout, 2002), Yechiam and his colleagues the study also found a non-significant trend for participants with AS to attend more to negative than positive outcomes of previous choices. The authors proposed that this was caused by a sub-group of individuals with AS (40% of their sample) with an extreme attentional bias to loss. Such a bias, if present, may account for the decision-related anxiety reported by some people with ASD, since they may perceive their previous decision-making more negatively than the neurotypical population.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Studies using other laboratory tasks also indicate possible differences in the decision-making of people with ASD compared to their neurotypical counterparts. Minassian, Paulus, Lincoln et al. (2007) found similar flexibility in the decision-making of adults with ASD compared to a neurotypical comparison group on a two-choice prediction task with a covertly manipulated error rate: both groups demonstrated a ‘win-stay/lose-shift’ strategy. However, unlike the neurotypical participants, the participants with ASD demonstrated a more pronounced ‘win-stay/lose-shift’ strategy when the error-rate was low. This suggests that people with ASD may be influenced to a greater extent by increases in the reinforcement schedule. Similarly, Damiano, Aloï, Treadway et al. (2012) found that adults with ASD were prepared to expend more effort for monetary rewards than neurotypical participants on the Effort Expenditure for Rewards Task (Treadway, Buckholtz, Schwartzman et al., 2009), but demonstrated reduced sensitivity to the reward contingencies. The authors related this to the high levels, among people with ASD, of circumscribed interests, often pursued at any cost. More broadly, it suggests that, in some contexts, people with ASD may be less flexible in their decision-making.

De Martino, Harrison, Knafo et al. (2008) have examined the effects of perceptual ‘framing’ on monetary decisions. The ‘framing effect’ describes the influence of the format in which the same options are presented (for example, by being worded in terms

of gains or losses) on choice (Tversky and Kahneman, 1981). Compared to participants from the neurotypical population, adults with ASD demonstrated less susceptibility to the framing effect, making more logically consistent choices. Furthermore, they did not demonstrate autonomic responses indicative of emotional involvement in the task. De Martino and his colleagues proposed that ASD reduces the typical reliance on emotional information and enhances logical consistency. There have been similar findings in the area of moral/social judgments (Brewer, Catmur, Stovcos et al., 2015). Such processing differences may affect many everyday situations because the available information is often ambiguous and/or incomplete (De Martino, Kumaran, Seymore et al., 2006).

Finally, Brosnan, Chapman and Ashwin (2014) found that adolescents with ASD gathered more information prior to making a decision on the ‘Jumping-to-conclusions Beads Task’, than a neurotypical comparison group, and proposed that ASD may be associated with a circumspect reasoning bias, leading to more careful decision-making. Such a proposal is consistent with self-reported slowness in decision-making (Luke et al., 2012), which again may reflect a more cautious approach to seeking and collating information (Luke, 2011). The results presented by DeMartino et al. (2008) and Brosnan et al., (2014) have recently been integrated to support a Dual Process Theory Account of ASD (Brosnan, Lewton and Ashwin, 2016). This account is based on the dual processing theories in cognitive psychology (e.g. Kahneman, 2003), which propose

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

that humans have two cognitive systems for decision-making: i) an intuitive style that is rapid and automatic, and ii) a deliberative style that is slower and effortful. In relating this account to people with ASD, Brosnan and his colleagues found, first, that increases in autistic traits in a general university undergraduate sample (assessed using the Autism Quotient, Baron-Cohen, Wheelwright and Skinner et al., 2001) were associated with a bias towards deliberative reasoning (assessed using the Rational Experiential Inventory, Pacini and Epstein, 1999), and, secondly, that young men with ASD responded in a more deliberative and less intuitive manner than neurotypical peers on the Cognitive Reflection Task.

The aim of this study was to examine empirically some of the possible ways in which decision-making may be different in ASD, when compared to the neurotypical population. This aim relates both to the earlier literature and to some of the difficulties reported in our previous study of self-reported experiences by people with ASD (Luke et al., 2012). Specifically, we wished to investigate : i) the relative attention paid to negative and positive outcomes of previous choices, with a sample size large enough to detect the non-significant difference trend reported by Johnson et al. (2006); ii) flexibility in decision-making; iii) the latency of decision-making; and iv) the tendency to sample information.

These processes were assessed using established laboratory tasks. While many paradigms for studying decision-making have been developed, such as questionnaires (e.g. Scott and Bruce, 1995) and assessments of biases (e.g. Kahneman, Slovic and Tversky, 1982), laboratory tasks can be used to present decisions visually, thereby reducing the requirement for imagination, which may be impaired in ASD (for example, Craig and Baron-Cohen, 1999), and provide objective measures of behaviour. In addition, such tasks are often used to detect impairments in decision-making (see, for example, Bechara et al., 1999; Manes et al., 2002; Tchanturia, Liao, Uher et al., 2007).

Methods

Participants

Thirty-eight adults with an ASD and forty neurotypical adults with no family history of ASD, aged 16 to 65 year took part; all participants gave written, informed consent prior to participation. The diagnostic inclusion criteria were:

1. Independent confirmation from a clinical or other relevant service of a diagnosis of an ASD, or diagnosis confirmed using the Autism Diagnostic Interview – Revised (ADI-R, Lord, Rutter and Le Couteur, 1994); and
2. Scores on one of two additional screening measures, the Autism Spectrum Quotient (AQ, Baron-Cohen et al., 2001) and the Autism Diagnostic Observation Schedule Module 4, (ADOS, Lord, Rutter, Goode et al., 1989),

consistent with the clinical or ADI-R diagnosis. If the clinical report lacked detail about the assessment procedure or did not report taking a developmental history (11 participants), inclusion criteria were scores on *both* the ADOS and AQ consistent with the clinical diagnosis.

Using these criteria, 34 out of 38 participants had ASD diagnoses confirmed with either the ADI-R or the ADOS. The remaining four participants were included because we received independent confirmation of their diagnosis from a clinical service describing a thorough assessment, and they scored above the clinical cut-off on the AQ. Due to resource constraints we only conducted our own ADI in the absence of independent confirmation of diagnosis from a clinical service. In six cases, an ADI had recently carried out as part of another, unrelated, study by the same research group.

Participants with ASD were recruited from volunteer databases and advertisements to members of autism support organisations. **Neurotypical** participants were recruited via local advertisements and by word-of-mouth. Recruitment and testing was carried out in 2009. Exclusion criteria for both groups were diagnoses of schizophrenia or related disorders, ADHD, bipolar depression, a tested Verbal IQ score below 90, significant and regular recreational drug use, and self-report of significant head trauma with lasting effects on cognition. The groups were matched for age, gender, and Verbal IQ (see

Table 1). Verbal IQ was assessed using the Wechsler Abbreviated Scale of Intelligence – Revised (WASI, Wechsler, 1999). All participants received payment as a token of appreciation.

The target sample size was 45 participants in each group, which theoretically would have detected a group difference on the computational model of the IGT of the same magnitude as that reported by Johnson et al. (2006) with almost 90% power at $\alpha = 0.1$ (one-tailed). Unfortunately, it was not possible to recruit more than 38 adults with ASD in the time available.

Measures

Decision-making tasks.

1. *Iowa Gambling Task* (IGT, see Bechara et al., 1999), to assess relative attention to negative and positive outcomes of previous choices (study aim i). In brief, participants are presented with a row of four decks of cards on a computer screen and asked to make repeated selections from the decks to win as much money as possible. Successful performance depends upon learning to select the two decks covertly associated with long-term gain rather than the two associated with long-term loss (for deck contingencies, see Table 2). To maintain motivation, participants were informed that they would receive an unspecified performance-related payment at the end of the task.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

The study aimed to present 150 trials; however, due to a technical problem, data were available only from the first 115 trials.

Data were analysed using the *Expectancy-Valence Learning (EVL)* model (Busemeyer and Stout, 2002), which quantifies, as the dependent variable, the relative attention paid to wins and losses of previous choices (the motivation parameter). The attention weight parameter ranges between 0 and 1, with 0 characterising a decision-maker greatly attracted to wins and indifferent to losses, and 1 characterising a decision-maker with a strong aversion to loss. Drawing on the findings of Johnson et al. (2006), we predicted that participants **with ASD** would demonstrate greater attention to negative outcomes, compared to the **neurotypical** participants. The proportion of advantageous selections over the task (task performance) is also reported.

2. *Cambridge Gamble Task* (CGT, Rogers, Everitt, Baldacchino et al., 1999), to assess flexibility (study aim ii) and latency (study aim iii) in decision-making. In this task, flexibility is assessed as responsiveness to changes in probabilistic information; typically, participants will risk a greater proportion of points as the probability of success increases (see Sinz, Zamarian, Benke et al., 2008). The CGT is part of the

Cambridge Neuropsychological Test Automated Battery (CANTAB, for details see <http://www.cambridgecognition.com/technology>). In brief, a row of 10 boxes is presented on a computer screen, with a ratio of red to blue boxes that differs on each trial (72 trials), ranging from 9:1 to 1:9. Participants are told that the computer has hidden a token under one of the boxes and they are asked to guess the colour of the box that is hiding the token. They are then asked to bet a proportion of their points on their choice being correct. The optional bets are presented 2.5 seconds apart in ascending or descending order depending on the condition of the task. The dependent variables are i) *risk-taking*, which is the mean proportion of points bet on each of the different trial types (i.e. ratio of blue to red) in each condition, and, when assessed across trial types, also provides an indication of flexibility in response to probabilistic information; and ii) *deliberation time (latency)*, the time from presentation of the stimuli to the participant touching their chosen colour on the touch screen. We predicted that participants with ASD would demonstrate reduced flexibility and longer decision-making latencies, compared to the **neurotypical** participants. The proportion of trials on which participants choose the most likely colour (*quality of decision-making*) is also reported because it provides information about the extent to which they understand, and are engaged by, the task.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

3. *Information Sampling Task* (IST, Clark, Robbins, Ersche et al., 2006), to assess information sampling (study aim iv). The IST is also part of the CANTAB. In brief, a 5x5 grid of 25 grey boxes on a computer-screen is presented, ‘behind’ each box is one of two hidden colours. Participants are instructed to open (by pressing) a box to reveal its colour and to open as many boxes as they wish before deciding which of the two colours is in the majority. Participants are presented with 10 trials in: i) a *Fixed-Win* condition, in which the total number of points available for a correct decision is 100, regardless of how many boxes are opened; and ii) a *Decreasing-Win* condition, in which the total number of points available for a correct decision starts at 250 and decreases by 10 points with every box that is opened. In both conditions, the cost of an incorrect decision is 100 points. The dependent variable is mean ‘*Probability Correct*’ ($P(\text{Correct})$), the mean probability that the decision-made will be correct, given the information available at the time of the decision (for the calculation, see Clark et al., 2006). In general, $P(\text{Correct})$ increases as more information is sampled and is considered to be a more ecologically valid variable than the number of boxes opened. This is because, under certain circumstances, the mean number of boxes opened can provide only a limited index of the amount of information gathered (see Clark, Roiser, Robbins et al., 2009). We predicted that, compared to the neurotypical group, the participants with ASD would sample information so as to increase the likelihood of making the correct decision.

Motor Speed. Motor speed on the touch screen computer was assessed using CANTAB Motor Screening Task (MOT). Participants used the tip of the forefinger of their dominant hand to touch 10 crosses as they appeared on the screen.

Mood. Levels of anxiety and depression were assessed using the Hospital Anxiety and Depression Scale (HADS, Zigmond and Snaith, 1983).

The questionnaires, WASI, and the MOT were completed at the beginning of the testing session. The order of the three decision-making tasks was counter-balanced across participants using a Latin Squares design to reduce potential order effects.

Data analysis

Prior to analysis, scores expressed as proportions of binomial events were transformed using the arcsine transformation, as recommended by Howell (1997). Other data types were transformed to reduce skew and improve suitability for parametric analysis.

Individual outliers (defined as more than three times the inter-quartile range from the upper or lower quartile after transformation) were excluded for parametric analyses.

Data were analysed using repeated-measures ANOVA and t-tests. Greenhouse-Geisser corrections were applied where the assumption of sphericity was not met. Non-

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

parametric equivalents to t-tests were used to compare data with distributions that remained non-normal after transformation.

Levels of anxiety and depression (HADS scores) were statistically controlled for where there was a significant relationship with the dependent variable. Such a relationship was assessed prior to analysis using: i) correlation analyses in the case of a single variable, and ii) including the measure as a covariate in the case of repeated measures ANOVA. There was no relationship between levels of depression and the dependent variables. However, there was a relationship between levels of anxiety and run lengths on the IGT and P(*Correct*) on the IST (described below).

Of note, nine participants with an ASD and one participant were taking antidepressant or anxiolytic medication, which may have effects on decision-making similar to those described by Deakin, Aitken, Dowson et al. (2004a). In the interests of caution, all analyses are carried out with and without these participants to check that their medications did not affect the results. Changes to the results are reported separately from the main analysis. Supplementary Table A presents descriptive information for the groups of participants not taking antidepressant or anxiolytic medication.

Results

Hospital Anxiety and Depression Scale

The participants with ASD reported significantly higher levels of anxiety and depression (see Table 1).

Motor Screening Task

The response latencies did not differ between the groups ($M_{ASD}=861.1$ msec, $SD=249.3$; $M_{neurotypical}=853.6$ msec, $SD=187.2$, $t(76)=0.151$, $p=.881$).

Iowa Gambling Task

Three participants in the neurotypical group were excluded because they responded abnormally; these participants made over eighty consecutive selections from one deck before sampling the other decks.

Task performance. The proportion of advantageous choices for each consecutive block of twenty-three selections is shown in Figure 1. The transformed proportions were analysed using a repeated-measures ANOVA of Block \times Group ($n_{ASD}=38$, $n_{neurotypical}=37$). There was a main effect of Block ($F(3.46, 252)=26.7$, $p<.001$), Group ($F(1, 73)=4.49$, $p=.037$), and a Block \times Group interaction ($F(3.46, 252)=4.44$, $p=.003$). A simple-effects analysis revealed that the interaction was due to a greater number of

selections from the advantageous decks by the ASD group in the final block of trials
($F(1, 73)=9.01, p=.004$).

EVL parameter. The fit of the *EVL* model was evaluated using the procedure described by Johnson et al. (2006). The fit of the model was satisfactory: the *EVL* model provided a better fit than the control (Bernoulli) model for 80% of the participants. The mean parameter estimate for attention to loss (range: 0 to 1, where 1 reflects high attention to loss) did not differ between the groups ($M_{ASD}=0.43, SD=0.27$; $M_{neurotypical}=0.48, SD=0.28, t(73)=-0.739, p=.462$). In contrast to Johnson et al. (2006), there was no evidence that a sub-group of participants with ASD demonstrated an extreme attentional bias to loss (four participants with ASD and five neurotypical participants had parameter estimates of 1).

The participants with ASD made significantly longer stretches of consecutive choices from the advantageous decks; these data were log transformed to reduce skew and included anxiety as a covariate (Mean maximum run length on the advantageous decks: $M_{ASD}= 29.6, SD=27.2$; $M_{neurotypical}=12.1, SD=16.2, F(1,72)=7.246, p=.009$).

Cambridge Gamble Task

Quality of decision-making. Compared to the neurotypical group, the most logical choice was selected by the participants with ASD on a smaller proportion of trials ($M_{ASD}=0.96$, $SD=0.068$; $M_{neurotypical}=0.98$, $SD=0.087$, Mann-Whitney U test, $p=.022$).

Exclusion of participants taking antidepressant or anxiolytic medication

Following exclusion of the 10 participants taking the antidepressant and anxiolytic medications, this difference between the groups was no longer statistically significant ($n_{ASD}=29$, $n_{neurotypical}=39$, $M_{ASD}=0.97$, $SD=0.012$; $M_{neurotypical}=0.98$, $SD=0.014$, Mann-Whitney U test, $p=.216$).

Flexibility. The proportion of points risked (see Figure 2) were arcsine transformed and analysed using a repeated-measures ANOVA of Trial type (9:1, 8:2, 7:3, 6:4, 5:5) \times Group. The groups did not differ in the proportion of points bet on the task (*risk-taking*), $F(1, 76)=1.407$, $p=.239$). Moreover, the Trial type \times Group interaction was not significant ($F(1.690, 128.429)=0.052$, $p=.926$), indicating that both groups flexibly adjusted their choices in response to changes in the probabilistic information.

Latency. Deliberation times (see Figure 3) were reciprocally transformed to reduce skew and analysed using a repeated-measures ANOVA of Trial type \times Group.

Compared to the neurotypical group, the participants with ASD took longer to make the decisions ($F(1, 76)=8.18, p=.005$). The Trial type \times Group interaction was not significant ($F(2.744, 208.567)=1.654, p=.182$).

Information Sampling Task

The mean $P(\text{Correct})$ scores (see Figure 4) were arcsine transformed and analysed using a repeated-measures ANOVA of Condition (Fixed Win, Decreasing Win) \times Group ($n_{\text{ASD}}=38, n_{\text{Neurotypical}}=40$). There was no effect of Group ($F(1, 76)=1.736, p=.0192$) or Condition \times Group interaction ($F(1, 76)=0.273, p=.603$).

Exclusion of participants taking antidepressant or anxiolytic medication

One participant in the neurotypical group was an outlier in the Decreasing Win condition and excluded from the analysis ($n_{\text{ASD}}=29, n_{\text{neurotypical}}=38$). There was a significant effect of anxiety when assessed using repeated measures ANCOVA ($F(1, 64)=5.510, p=0.022$), which appeared to reflect a non-significant, but negative correlation between anxiety and the dependent variables; anxiety was therefore included as a covariate in the between-group analysis. There was main effect of Group ($F(1, 64)=9.713, p=.003$), suggesting that the participants with ASD sampled information to a higher probability of being correct than the neurotypical group.

Discussion

This paper reports an empirical investigation of several decision-making processes in intellectually able adults with ASD to complement previous subjective reports of difficulties: decision-making performance, attention to negative and positive outcomes, flexibility to changes in probabilistic information, speed of decision-making, and information sampling. These processes were assessed to establish whether some of the experiences reported by adults with ASD are consistent with any differences in decision-making processes measured on laboratory tasks.

Compared to the neurotypical participants, the participants with ASD demonstrated significantly longer decision-making latencies on the CGT, and, a tendency to make decisions with a higher probability of being correct on the IST. These findings are consistent with self-reports of a tendency to spend excessive time collecting and collating information (Luke, 2011), reaching a decision (Luke et al., 2012; Winter, 2003) and indecisiveness (Johnson et al., 2006). Longer deliberation times did not appear to reflect impairments in motor speed, and are consistent with previous research demonstrating reduced response speed to comprehension questions in ASD (Bowler, 1997). It is, of course, possible that the increased latency reflects slower perceptual processing of the number of coloured boxes. However, this interpretation is not

supported by a previous study demonstrating comparable inspection times between children with and without ASD (Wallace, Anderson and Happé, 2009).

The tendency for participants with ASD to sample more information than the neurotypical participants on the IST is consistent with the report by Brosnan et al. (2014) that adolescents with ASD sampled more information prior to deciding from which jar a coloured bead may have been drawn. This was formulated as a ‘circumspect reasoning bias’. We support this formulation by demonstrating that participants with ASD sampled more information even when penalised for doing so (in this case, by a loss of points in the Decreasing Win condition, in which participants lost 10 points for every box sampled).

Contrary to the findings of Johnson et al. (2006), the *EVL* model analysis of the IGT data did not suggest that participants with ASD were more attentive than the neurotypical participants to negative rather than positive outcomes of previous choices. Moreover, there was no evidence of a sub-group of participants with ASD with an extreme attentional bias to loss. The differences between our findings and those of the previous study may reflect: i) the difference in ages of the sample populations (adolescents in Johnson et al., 2006)), since decision-making is affected by age (see Deakin, Aitken, Robbins et al., 2004b); ii) a poorer fit of the *EVL* model (a satisfactory

fit for only 55% of participants in Johnson et al. (2006), compared to 80% in the present study); and iii) the difference in the study sample sizes (15 AS participants in Johnson et al., 2006). Overall, the findings from the present study suggest the difficulties reported by people with ASD, such as anxiety about decision-making, are not accounted for by increased attention to negative outcomes of previous decisions.

Of interest, however, compared to the neurotypical participants, the participants with ASD made more advantageous choices on the IGT. This finding, again, differs from the results of Johnson et al. (2006), and from other researchers who have used the IGT (Yechiam et al., 2010, Faja et al., 2013, and Mussey et al., 2015. However, our findings are, consistent with those reported by South et al. (2014). Given that all the above studies involved children or adolescents of at least average intellectual ability, it is possible that the apparent discrepancy between different studies reflects sample size, since the largest samples were those of the present study (n=38) and South et al. (n=48). Adding weight to the results of South et al. (2014), our findings extend the age range for which superior performance on the IGT in ASD has been demonstrated.

We were surprised that, on the IGT, three of the neurotypical participants made over eighty selections from a single deck before sampling from the other decks. This was one of the advantageous decks. It is possible, though unlikely, that these participants

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

had previous experience of the task, though they did not volunteer any relevant information. More plausibly, perhaps, their response reflected limited engagement and boredom with the task. No participants with ASD appeared to respond abnormally and they all sampled each of the decks. The tendency for the superior performance of those with ASD (characterised by more consistent advantageous selections in the later stages of the task) may reflect speedier comprehension of the contingencies associated with long-term gains, and/or greater ability to focus on maintaining a more repetitive but logically advantageous strategy.

The tendency for participants with ASD to make more advantageous selections on the IGT is consistent with subjective and experimental reports of enhanced logic in decision-making in ASD (De Martino et al., 2008; Luke et al., 2012), as well as the superior systemising hypothesis of ASD (Baron-Cohen, 2009). Moreover, a tendency to attempt a more logical analysis of decisions, which demand time and cognitive resources, could account for the perception of ‘effortful’ processing reported by people with ASD (Luke et al., 2012).

The other decision-making processes assessed (attention to negative and positive outcomes, and flexibility) did not differ between the groups. One possible explanation, though it cannot easily be reconciled with our positive findings on other tasks, is that

they may reflect the difference between the laboratory tasks, which present simple decisions in controlled and quiet surroundings that are likely to enable participants with ASD to perform at their best, and decisions in real life, which may involve multiple response options, busy environments, be of personal significance, and often have to be made under pressure of time (c.f. Sainsbury's (2000) description of the difficulty in choosing food "on the spot" was given in the context of the lunch queue in a school canteen, p101).

Overall, the profile of results observed in this study (slower, logical and perhaps more effortful decision-making, with non-significant differences for attention to positive and negative outcomes) seems to support a Dual Process Theory Account of ASD (Brosnan et al., 2016). Specifically, this account suggests that ASD is associated with a consistent bias towards slower, deliberative decision-making and away from intuitive decision-making. While such a reasoning style may be beneficial for some tasks (e.g. mathematics), it may contribute to the characteristic difficulty in social communication in ASD, which requires the rapid integration of social and, often, contextual information.

Levels of anxiety, assessed using the HADS, appeared to affect the results for two of the measures in the present study. First, we found that anxiety correlated positively with

longer stretches of consecutively advantageous choices; this suggests that higher levels of anxiety in the ASD group may contribute to the observed group effect. Previous research findings regarding the relationship between anxiety and IGT performance are mixed (see, for example Miu et al., 2008; Werner, Duschek and Schandry, 2009). However, the relationship we observed is consistent with studies suggesting that higher levels of trait anxiety are associated with reduced risk-taking choices (Giorgetta, Grecucci, Zuanon et al., 2012). Secondly, there was a significant effect of anxiety on *P(Correct)* on the IST. Interestingly, for this analysis, the group difference found on the IST appeared to be moderated by anxiety: higher levels of anxiety were weakly associated with reduced information sampling. A similar effect has been observed in neurotypical participants with experimentally-induced anxiety, who tended to ‘jump to conclusions’ when completing the beads task (Lincoln, Lange, Burau et al., 2010). In noting this, however, we concur with Lincoln and her colleagues that there may be significant individual variation in the impact of anxiety on reasoning styles.

This study has limitations. As discussed above, the finding that the participants with ASD took longer to make decisions on the CGT may reflect an overall weakness in cognitive speed, rather than processes involved specifically in decision-making. Inclusion of a measure of general cognitive processing speed would have provided an opportunity to identify, and control for, any differences in cognitive speed between the

groups. In addition, although the decision-making tasks used have been established to identify cognitive differences between clinical groups, they clearly lack ecological validity, both in their content and the laboratory conditions in which they are carried out. Moreover, the tasks did not include elements of social decision-making, which is proving to be an area of direct relevance in ASD (for example, Brewer et al., 2015).

In addition, the age range of the participants was rather wide. Since age is an important factor in decision-making (Deakin, Aitken, Robbins et al., 2004), the statistical analyses may have been more powerful in a narrower age range of participants. However, the groups did not significantly in mean age or in the distribution of age. While inclusion of age as a covariate might be possible, it was not included here because statistical control of a confounding variable is necessary only when the confounding variable differs between the independent variables (Boniface, 1995). In this case, the influence of age was removed optimally at the design stage.

Research implications

Given the diverse findings on the IGT between different studies, further research aiming to understand these differences is desirable. In addition, the relationship between anxiety and decision-making appears to be complicated, depending upon the decision-making context, and potentially the individual characteristics of the decision-maker.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Given the importance of anxiety in the lives of both children and adults with the condition (Kim et al., 2000; Skokouskas & Gallagher, 2010), such studies are rather urgently required. More generally, future studies relating to decision-making should consider assessing decision-making in ASD using both tasks and contexts with greater ecological validity. A starting point for such research could be the adaptation of the paradigms developed by Braeutigam and his colleagues (Ambler, Braeutigam, Stins et al., 2004; Braeutigam, Stins, Rose et al., 2001). Their tasks involve shopping decisions (a class of decision that was identified as problematic in several of the survey accounts) and have enabled identification of several neural processes involved in decision-making, such as silent vocalisation and the effect of familiarity on choice. Other paradigms could be developed that present medical and other legally-significant decisions, or decisions with several stages, such as planning a journey. The development of such tasks may promote investigations of the difficulties reported by people with ASD that can more easily be linked to support for individuals with ASD and their care-givers.

Practical implications

Despite the limitations of the study, the findings from this substantial sample of people with ASD demonstrate that, under experimental conditions, performance on tasks involving the decision-making processes of quality/logic (IGT) and flexibility (CGT) is

not impaired and indeed, can be of comparable, or even superior, quality to that of neurotypical adults. Unfortunately, the experiences of everyday decision-making by people with ASD remain negative (Luke et al., 2012). Previously, we made a number of recommendations intended to improve their experiences, for example, that encouragement and reassurance were needed to challenge the usual self-perceptions of decision-making of our respondents, and, as far as possible, that time-constraints should be relaxed to minimise feelings of pressure to make a choice. The findings of this study provide some empirical basis for these recommendations. For example, the evidence that, even for the very straightforward task involving simple probability (the CGT), and under favourable laboratory conditions, participants with ASD needed longer to deliberate before making a choice supports our recommendation that people with the condition should not feel rushed into making decisions. This is particularly important where the decision is legally-significant or potentially life-changing (for example, whether to give or withhold consent to a complex medical procedure or a change of accommodation). Similarly, the enhanced information-sampling demonstrated by our ASD participants on a visual task (the IST) supports our previous recommendation about minimizing information that is irrelevant to the decision to be made. The provision of relevant material, clearly set out, may assist people with ASD to focus on the analytical part of the process, which appears to be a strength associated with the condition, without becoming distracted, and overwhelmed by, collecting more and

more information. . Finally, given that the majority of ASD participants in this study had levels of anxiety above the normal range, consideration should be given to the possible effects of anxiety on their decision-making; access to psychological or pharmacological therapies to reduce anxiety may also be beneficial.

Our recommendations in relation to supporting decision-making remain general: the range of responses of the participants with ASD emphasises the need to provide practical support based on individuals’ assessed strengths and weaknesses. Nevertheless, since they are evidence-based, these recommendations may be of assistance in providing guidance to supplement the recent, and very welcome, attempts to create ‘autism-friendly’ social (<https://www.theguardian.com/social-care-network/2016/jun/10/no-silence-plea>) and physical (<http://www.scottishautism.org/about-autism/research-and-training/design-autism>) environments.

Conclusion

The findings indicate that adults with ASD can, at least in laboratory situations circumstances, make as good or overall better decisions than adults in the general population. However, consistent with the subjective decision-making difficulties reported, we found that, compared to a **neurotypical** comparison group, this sample of

intellectually able adults with ASD demonstrated slower decision-making speed, a tendency to sample more information prior to making decisions (consistent with the circumspect reasoning bias hypothesis), and more logical choices, perhaps reflecting more effortful processing. These findings provide an empirical basis for our previous recommendations about supporting decision-making by people with ASD (Luke et al. 2012).

References

- Ambler, T, Braeutigam, S, Stins, J, Rose, S & Swithenby, S (2004) Salience and choice: neural correlates of shopping decisions. *Psychology and Marketing* 21: 247-261.
- Baron-Cohen, S (2009) Autism: the Empathizing-Systemizing (E-S) theory. *Annals of the New York Academy of Sciences* 1156: 68-80.
- Baron-Cohen, S, Wheelwright, S, Skinner, R, Martin, J & Clubley, E (2001) The Autism-Spectrum Quotient (AQ): evidence from Asperger syndrome/high-functioning autism, males and females, scientists and mathematicians. *Journal of Autism and Developmental Disorders* 31: 5-17.
- Bechara, A, Damasio, H, Damasio, AR & Lee, GP (1999) Different contributions of the human amygdala and ventromedial prefrontal cortex to decision-making. *The Journal of Neuroscience* 19: 5473-5481.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Boniface, DR (1995) *Experiment design and statistical methods for behavioural and social research*. London: Chapman & Hall/CRC.

Bowler, DM (1997) Reaction times to mental state and non-metal state questions in false belief tasks by high-functioning individuals with autism. *European Child and Adolescent Psychiatry* 6: 160-165.

Braeutigam, S, Stins, JF, Rose, S, P.R., Swithenby, S, J. & Ambler, T (2001) Magnetoencephalographic signals identify stages in real-life decision processes. *Neural Plasticity* 8: 241-254.

Brewer, R., Catmur, C., Stoycos, S., Marsh, AA., Cardinale, EM. & Cook, R. (2015) The impact of autism depctrum disorder and alexythymia on judgements of moral acceptability. *Journal of Abnormal Psychology* 124: 589 – 595.

Brosnan, M, Chapman, E & Ashwin, C (2014) Adolescents with autism spectrum disorder show a circumspect reasoning bias rather than 'jumping-to-conclusions'. *Journal of Autism and Developmental Disorders* 44: 513-20.

Brosnan, M, Lewton, M & Ashwin, C (2016) Reasoning on the Autism Spectrum: A Dual Process Theory Account. *Journal of Autism and Developmental Disorders* 46: 2115-25.

- 1
2
3
4
5
6
7
8
9 Busemeyer, JR & Stout, JC (2002) A contribution of cognitive decision models to
10 clinical assessment: decomposing performance on the Bechara Gambling Task.
11 *Psychological Assessment* 14: 253-262.
12
13
14
15
16 Clark, L, Robbins, TW, Ersche, KD & Sahakian, BJ (2006) Reflection impulsivity in
17 current and former substance abusers. *Biological Psychiatry* 60: 515-522.
18
19
20
21 Clark, L., Roiser, J., Robbins, RW., & Sahakian, BJ (2009) Disrupted 'reflection'
22 impulsivity in cannabis users but not current or former ecstasy users. *Journal of*
23 *Psychopharmacology* 23(1): 14 - 22.
24
25
26
27
28
29 Craig, J & Baron-Cohen, S (1999) Creativity and imagination in autism and Asperger
30 syndrome. *Journal of Autism and Developmental Disorders*, 29: 319-326.
31
32
33
34 Damiano, CR, Aloia, J, Treadway, M, Bodfish, JW & Dichter, GS (2012) Adults with
35 autism spectrum disorders exhibit decreased sensitivity to reward parameters
36 when making effort-based decisions. *Journal of Neurodevelopmental Disorders*
37
38
39
40 4: 1866-1955.
41
42
43 De Martino, B, Harrison, NA, Knafo, S, Bird, G & Dolan, RJ (2008) Explaining
44 enhanced logical consistency during decision making in autism. *The Journal of*
45
46
47
48 *Neuroscience* 28: 10746-10750.
49
50
51
52
53
54
55
56
57
58
59
60

De Martino, B, Kumaran, D, Seymore, B & Dolan, RJ (2006). Frames, biases, and rational decision-making in the human brain. *Science* 313: 684-687.

Deakin, JB, Aitken, MRF, Dowson, JH, Robbins, TW & Sahakian, BJ (2004a) Diazepam produces disinhibitory cognitive effects in male volunteers. *Psychopharmacology* 173: 88-97.

Deakin JB, Aitken MRF, Robbins TW, Sahakian BJ. (2004) Risk taking during decision-making in normal volunteers changes with age. *Journal of the International Neuropsychological Society* 10:590 - 8.

Edwards, W (1954) The theory of decision making. *Psychological Bulletin* 51: 380-417.

Etzioni, A (1988) Normative-affective factors: towards a new decision-making model. *Journal of Economic Psychology* 9: 125-150.

Faja, S, Murias, M, Beauchaine, TP & Dawson, G (2013) Reward-based decision making and electrodermal responding by young children with autism spectrum disorders during a gambling task. *Autism Research* 6: 494-505.

Frederick, S (2005) Cognitive reflection and decision making. *The Journal of Economic Perspectives* 19(4): 25-42.

Gillott, A, Furniss, F & Walter, A (2001) Anxiety in high-functioning children with autism. *Autism* 5: 277- 286.

- Giorgetta, C, Grecucci, A, Zuanon, S, Perini, L, Balestrieri, M, Bonini, N, Sanfey, AG & Brambilla, P (2012) Reduced risk-taking behavior as a trait feature of anxiety. *Emotion* 12: 1373-1383.
- Grandin, T (2000). My mind is a web browser: how people with autism think. *Cerebrum* 2: 14-22.
- Hill, EL (2004) Evaluating the theory of executive dysfunction in autism. *Developmental Review* 24: 189-233.
- Howell, DC (1997). *Statistical methods for psychology*. Belmont: Wadsworth.
- Huitt, WG (1992) Problem solving and decision making: consideration of individual differences using the Myers-Briggs indicator. *Journal of Psychological Type* 24: 33-44.
- Johnson, SA, Yechiam, E, Murphy, RR, Queller, S & Stout, JC (2006) Motivational processes and autonomic responsivity in Asperger's disorder: evidence from the Iowa Gambling Task. *Journal of the International Neuropsychological Society* 12: 668-676.
- Kahneman, D (2003) A perspective on judgment and choice: mapping bounded rationality. *American Psychologist* 58: 697-720.
- Kahneman, D, Slovic, P & Tversky, A (1982). *Judgment under Uncertainty: Heuristics and Biases*. Cambridge: Cambridge University Press.

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Kim, JA, Szatmari, P, Bryson, SE, Streiner, DL. & Wilson F (2000). The prevalence of anxiety and mood problems among children with autism and Asperger syndrome. *Autism* 4: 117 – 132.

Lincoln, TM, Lange, J, Burau, J, Exner, C & Moritz, S (2010) The effect of state anxiety on paranoid ideation and jumping to conclusions: an experimental investigation. *Schizophrenia Bulletin* 36: 1140-1148.

Lord, C, Rutter, M, Goode, S, Heemsberger, J, Jordan, H, Mawhood, L & Schopler, E (1989) Autism diagnostic observation schedule: a standardized observation of communicative and social behavior. *Journal of Autism and Developmental Disorders* 19: 185-212.

Lord, C, Rutter, M & Le Couteur, A (1994) Autism Diagnostic Interview - Revised. *Journal of Autism and Developmental Disorders* 24: 659-686.

Luke, L. (2011) *Decision-making in Autism Spectrum Conditions*. PhD Thesis, University of Cambridge, UK.

Luke, L, Clare, ICH , Ring, H, Redley, M & Watson, P (2012). Decision-making difficulties experienced by adults with autism spectrum conditions. *Autism* 16: 612-621.

- Manes, F, Sahakian, B, Clark, L, Rogers, R, Antoun, N, Aitken, M & Robbins, T (2002)
Decision-making processes following damage to the prefrontal cortex. *Brain*
125: 624-639.
- Marson, DC, Chatterjee, A, Ingram, K & Harrell, LE (1996) Toward a neurologic
model of competency: cognitive predictors of capacity to consent in Alzheimer's
disease using three different legal standards. *Neurology* 46: 666-672.
- Minassian, A, Paulus, M, Lincoln, A & Perry, W (2007) Adults with autism show
increased sensitivity to outcomes at low error rates during decision-making.
Journal of Autism and Developmental Disorders 37: 1279-1288.
- Miu, AC, Heilman, RM & Houser, D (2008). Anxiety impairs decision-making:
psychophysical evidence from an Iowa Gambling Task. *Biological Psychology*
77: 353-358.
- Mussey, JL, Travers, BG, Klinger, LG & Klinger, MR (2015) Decision-making skills in
ASD: performance on the Iowa Gambling Task. *Autism Research* 8: 105-114.
- Pacini, R & Epstein, S (1999) The relation of rational and experiential information
processing styles to personality, basic beliefs, and the ratio-bias phenomenon.
Journal of Personality and Social Psychology 76: 972-987.
- Rogers, RD, Everitt, BJ, Baldacchino, A, Blackshaw, AJ, Swainson, R, Wynne, K,
Baker, NB, Hunter, J, Carthy, T, Booker, E, London, M, Deakin, JFW,

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Sahakian, BJ & Robbins, TW (1999) Dissociable deficits in the decision-making cognition of chronic amphetamine abusers, opiate abusers, patients with focal damage to prefrontal cortex, and tryptophan-depleted normal volunteers: evidence for monoaminergic mechanisms. *Neuropsychopharmacology* 20: 322-339.

Sainsbury, C (2000). *Martian in the playground: understanding the schoolchild with Asperger's syndrome*. England: Lucky Duck Publishing Ltd.

Scott, SG & Bruce, RA (1995) Decision-making style: the development and assessment of a new measure. *Educational and Psychological Measurement* 55: 818-831.

Sinz, H, Zamarian, L, Benke, T, Wenning, GK & Delazer, M (2008) Impact of ambiguity and risk on decision-making in mild Alzheimer's disease. *Neuropsychologia* 46: 2043-2055.

Skokauskas, N. & Gallagher, L (2010) Psychosis, affective disorders and anxiety in autism spectrum disorder: prevalence and nosological conditions. *Psychopathology* 43: 8 – 16.

South, M, Chamberlain, PD, Wigham, S, Newton, T, Le Couteur, A, McConachie, H, Gray, L, Freeston, M, Parr, J, Kirwan, CB & Rodgers, J (2014) Enhanced decision making and risk avoidance in high-functioning autism spectrum disorder. *Neuropsychology* 28: 222-228.

- 1
2
3
4
5
6
7
8
9 Stallen, M (2006). *Excel application of the Expectancy-Valence model*. Technical
10
11 Report, Amerstam: University of Amsterdam.
12
13
14 Tchanturia, K, Liao, P, Uher, R, Lawrence, N, Treasure, J & Campbell, IC (2007) An
15
16 investigation of decision making in anorexia nervosa using the Iowa Gambling
17
18 Task and skin conductance measurements. *Journal of the International*
19
20 *Neuropsychological Society* 13: 635-641.
21
22
23 Treadway, MT, Buckholtz, JW, Schwartzman, AN, Lambert, WE & Zald, DH (2009)
24
25 Worth the 'EEfRT'? The effort expenditure for rewards task as an objective
26
27 measure of motivation and anhedonia. *Plos One* 4: 0006598.
28
29
30 Tversky, A & Kahneman, D (1981) The framing of decisions and the psychology of
31
32 choice. *Science* 211: 453 - 458.
33
34
35 Wallace, GL, Anderson, M & Happé, F (2009) Brief report: Information processing
36
37 speed is intact in autism but not correlated with measured intelligence. *Journal*
38
39 *of Autism and Developmental Disorders* 39: 809-814.
40
41
42 Wechsler, D (1999) *Wechsler Abbreviated Scale of Intelligence*. San Antonio: The
43
44 Psychological Corporation, Harcourt Brace & Company.
45
46
47 Werner, NS, Duschek, S & Schandry, R (2009) Relationships between affective states
48
49 and decision-making. *International Journal of Psychophysiology* 74: 259-265.
50
51
52
53
54
55
56
57
58
59
60

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60

Winter, M (2003). *Asperger syndrome: what teachers need to know*. London: Jessica
Kingsley Publishers.

Yechiam, E, Arshavsky, O, Shamay-Tsoory, SG, Yaniv, S & Aharon, J (2010) Adapted
to explore: reinforcement learning in autistic spectrum conditions. *Brain and
Cognition* 72: 317-324.

Yechiam, E, Busemeyer, JR, Stout, JC & Bechara, A (2005) Using cognitive models to
map relations between neuropsychological disorders and human decision-
making deficits. *Psychological Science* 16: 973-978.

Zigmond, AS & Snaith, RP (1983) The Hospital Anxiety and Depression Scale. *Acta
Psychiatrica Scandinavica* 67: 361-370.

Table 1. *Participant characteristics*

Characteristic	ASD group (n = 38)	Control Group (n = 40)	Test of group difference
% male	65.8	67.5	$\chi^2=0.03, p=0.87$
Mean age in years	34.1 (15.4)	34.0 (14.7)	<i>Mann-Whitney U, p=0.91</i>
Mean tested Verbal IQ	116.4 (10.2)	114.2 (11.9)	$t(76)=0.89, p=0.38$
HADS: Anxiety	10.6 (3.6)	5.4 (2.7)	$t(76)=7.27, p<0.001$
HADS: Depression	4.7 (3.2)	1.6 (1.6)	<i>Mann-Whitney U, p<0.001</i>

Table 1 shows a summary of the characteristics of both groups. Mean (SD). These results did not change when the participants taking the antidepressant or anxiolytic medication were excluded.

HADS = Hospital Anxiety and Depression Scale.

Table 2. *Contingency scheme for the IGT (as used by Bechara et al. 1994)*

Deck	Win	Lose	Net profit over 10 trials
A	\$50 every card	\$50 with probability $\frac{1}{2}$	+\$250
B		\$250 with probability $\frac{1}{10}$	
C	\$100 every card	\$150, 200, 250, 300 or 350 each with probability $\frac{1}{10}$	-\$250
D		\$1250 with probability $\frac{1}{10}$	

Figure 1. Performance on the IGT for each group of participants

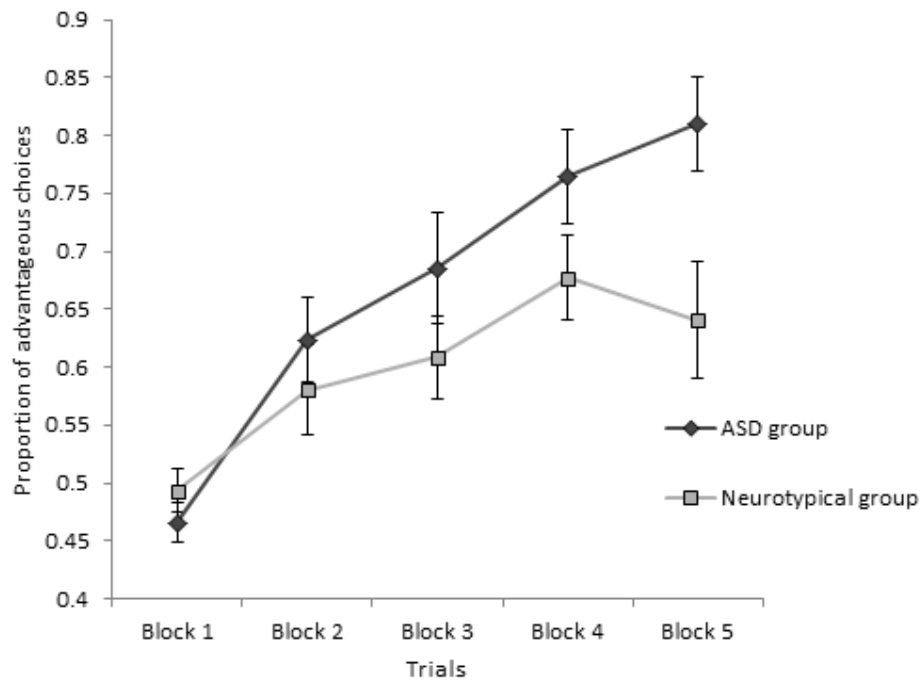


Figure 1 shows the mean proportion of choices from the advantageous decks for each consecutive block of 23 selections for both groups of participants. Error bars represent the standard error of the mean.

Figure 2. Mean proportion of points bet across different trial types of the CGT

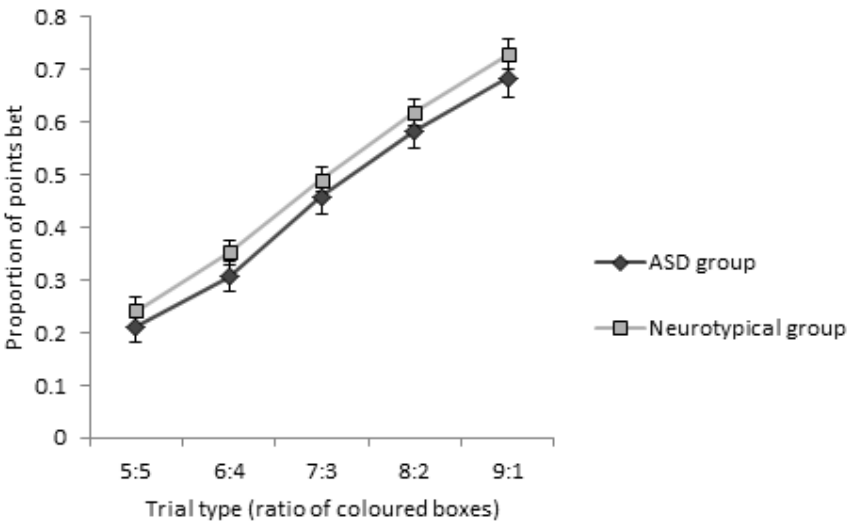


Figure 2 shows the mean proportion of points bet on the different trial types of the CGT (averaged across condition) for both groups of participants. Error bars represent the standard error of the mean.

Figure 3. Mean deliberation times for each group of participants on the CGT

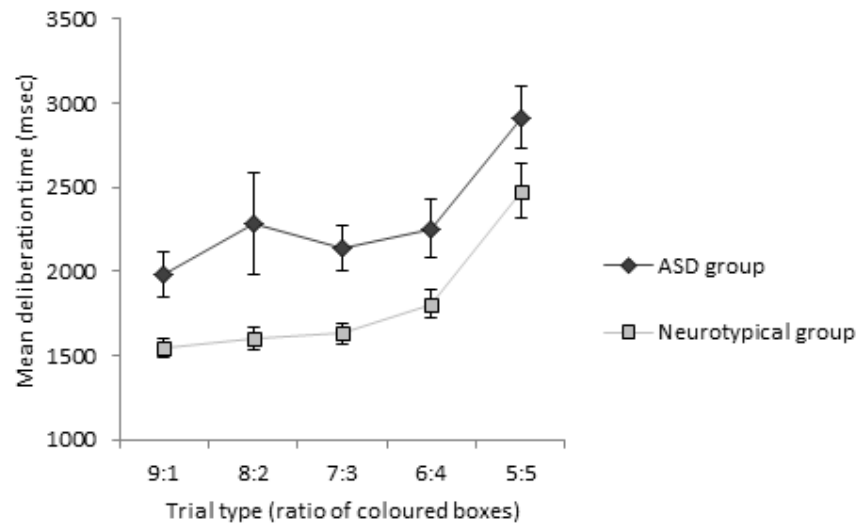


Figure 3 shows the mean deliberation times for both groups of participants on all trial types of the CGT. Error bars represent one standard error of the mean.

Figure 4. *The mean P(Correct) scores for each group of participants on the IST*

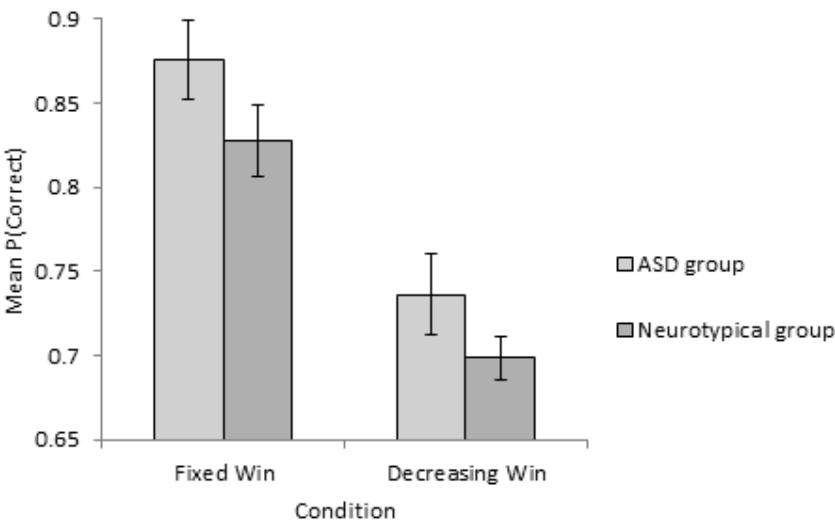


Figure 4 shows the raw mean $P(\text{Correct})$ scores for both groups of participants who were not taking antidepressant or anxiolytic medication. $P(\text{Correct})$ is the probability that the participants' choice would have been correct at the time of the decision, based on the information available. Error bars are the standard error of the mean.

Table A. *Participant characteristics (excluding participants taking antidepressant or anxiolytic medication)*

Characteristic	ASD group (n = 38)	Control Group (n = 40)	Test of group difference
% male	62.1	69.2	$\chi^2=0.38, p=0.54$
Mean age in years	30.7 (14.0)	34.2 (14.9)	<i>Mann-Whitney U, p=0.24</i>
Mean tested Verbal IQ	116.7 (11.0)	114.1 (12.0)	$t(66)=0.90, p=0.37$
HADS: Anxiety	10.3 (3.56)	5.3 (2.7)	$t(66)=6.74, p<0.001$
HADS: Depression	4.1 (2.7)	1.6 (1.6)	<i>Mann-Whitney U, p<0.001</i>

Table 2 shows a summary of the characteristics of both groups, excluding participants taking the antidepressant or anxiolytic medication. Mean (SD). HADS = Hospital Anxiety and Depression Scale.